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FORECASTING SYSTEMS TECHNICAL NOTE NO.7

SUMMARY of TROPICAL CYCLONE ACTIVITY and FORECASTS in the 1996 NORTHERN HEMISPHERE SEASON

J.T.HEMING

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Forecasting Systems
Meteorological Office
London Road
Bracknell, Berkshire
RG12 2SZ

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1. INTRODUCTION

A summary of tropical cyclone activity in the northern hemisphere for the 1996 season is presented below together with an assessment of the performance of the global model in predicting the tracks of these tropical cyclones.

Tropical cyclones are experienced in the North Pacific, North Atlantic and North Indian Oceans and nearby tropical seas. For the purpose of tropical cyclone verification the northern hemisphere is divided in to four basins; the North-West Pacific (west of 180°E to the Malay Peninsula), the North-East Pacific (east of 180°E), the North Atlantic and the North Indian Ocean (west of the Malay Peninsula). Mean error statistics for each basin are presented together with a table of statistics for the whole northern hemisphere. The global model produces a 6-day forecast every 12 hours. Verification is performed at 24 hour intervals up to forecast time T+120.

The present global model has a resolution of 1.25°x 0.83°x 19 levels. This is equivalent to a horizontal resolution of 139km x 93km at the equator. The tropical cyclone verification scheme identifies the centre of a tropical cyclone in the model by locating a local maximum of relative vorticity at 850hPa. A surface fitting technique is used to locate the centre accurately.

The terms used in the statistics tables are explained below :-

Possibly verified - No. of forecasts fulfilling requirements 1, 2 & 4 below.
Detection Rate - Percentage of possibly verified forecasts which also fulfil requirement 3 below.
Mean DX - Mean of positional errors in the East-West direction.
Mean DY - Mean of positional errors in the North-South direction.
Mean AT - Mean of positional errors in the Along Track direction.
Mean CT - Mean of positional errors in the Cross Track direction.
Skill - Percentage skill of model against CLIPER.
Mean DPE - Mean of direct positional errors.
All errors are measured in kilometres except where indicated.

(*) 1. Observed maximum wind at least 31 knots at the verifying time.
2. Forecast tropical cyclone centre equatorwards of 40 degrees.
3. Forecast tropical cyclone centre relative vorticity above a critical limit for verification (0.55×10^{-4} per second).
4. Observation within 6 hours of verifying time present for use in verification.

Forecast skill is defined as:- $\frac{\text{CLIPER DPE - Model DPE}}{\text{CLIPER DPE}} \times 100\%$

Positive skill indicates the model forecast is better than CLIPER.
Negative skill indicates the CLIPER forecast is better than the model.

A diagrammatic explanation of other error statistics and their sign conventions can be found in Appendix A. Full details of the TC verification scheme can be found in *nwp* Gazette, Vol.1, No.2, December 1994.

Advisory positions from JTWC Guam, NHC Miami and CPHC Honolulu are used as verifying observations of storm location when track verification is carried out immediately after a storm has ended. Best track data from these centres has been obtained for this season's storms and the track forecasts verified again. Statistics for verification against best-track observations are presented in detail. Some statistics for verification against real-time observations are included for the purposes of a comparison. Some mean error statistics for last season are also included for the purposes of a comparison. Forecast tracks are only verified when a depression reaches tropical storm status.

2.TROPICAL CYCLONE ACTIVITY

	NWP	NEP	NAT	NI	TOTAL
Total number active 1995	35(25)	11(10)	21(19)	4(4)	71(58)
Total number active 1996	43(30)	13(8)	13(13)	8(8)	77(59)

Basin name abbreviations:- NWP = North-West Pacific (west of 180°E)
NEP = North-East Pacific (east of 180°E)
NAT = North Atlantic
NI= North Indian

The number in brackets indicates the number of depressions which reached tropical storm status (maximum sustained wind above 33 knots).

3. SUMMARY OF ALL NORTHERN HEMISPHERE STORMS

3.1 North-West Pacific Basin Storms

Table of Mean Error Statistics

	T+0	T+24	T+48	T+72	T+96	T+120
Possibly Verified	341	282	229	182	139	102
Detection Rate (%)	100	99	97	92	90	88
Mean DX	0	-13	-39	-24	28	59
Mean DY	12	47	73	87	99	116
Mean AT	1	-7	-15	-41	-46	-3
Mean CT	3	-4	-16	-11	55	139
Mean Skill (%)	****	-8	30	39	****	****
* 1995 Skill (%)	****	2	23	23	****	****
RT Skill (%) #	****	12	36	42	****	****
Mean DPE	56	160	263	396	509	631
* 1995 DPE	60	180	297	439	691	826
RT DPE #	45	159	261	396	506	629

* DPE and skill for all North-West Pacific storms in 1995 season

\# DPE and skill in 1996 calculated using real time observations as opposed to best track.

Comments :

A plot of the observed tracks of all storms in this basin can be found in Fig. 1.

There were five more tropical storms this season than last in the North-West Pacific basin. More storms formed further east than did in 1995, but there were still very few east of 150°E. Forecast errors were the lowest ever in this basin. The T+72 error fell below 400km for the first time. Skill scores were higher than last season at T+48 and T+72. There was an overall slow bias and a slight right-of-track bias at T+96 and T+120 in forecasts this season. The detection rate for storms was very good with 88% of storms being successfully retained 5 days into the forecast.

Figs. 2 and 3 show forecast errors and skill scores for the last few seasons.

3.2 North-East Pacific Basin Storms

Table of Mean Error Statistics

	T+0	T+24	T+48	T+72	T+96	T+120
Possibly Verified	61	43	26	15	8	4
Detection Rate (%)	100	91	38	20	0	0
Mean DX	-4	3	22	243	****	****
Mean DY	-35	-117	-123	-141	****	****
Mean AT	-27	-68	-122	-267	****	****
Mean CT	-20	-73	-159	-112	****	****
Mean Skill (%)	****	-53	-1	1	****	****
* 1995 Skill (%)	****	-17	27	29	****	****
RT Skill (%) #	****	-13	-3	-5	****	****
Mean DPE	76	209	319	340	****	****
* 1995 DPE	56	164	259	343	358	521
RT DPE #	68	207	322	361	****	****

* DPE and skill for all North-East Pacific storms in 1995 season

\# DPE and skill in 1996 calculated using real time observations as opposed to best track.

Comments :

A plot of the observed tracks of all storms in this basin can be found in Fig. 4.

There were two less tropical storms this season than last in the North-East Pacific basin. Nearly all storms were concentrated close to the Mexican coast and only one passed west of 120°W amking this a very inactive season. Forecast errors were slightly higher than last season and skill scores were considerably lower. There was a slow and left-of-track bias in forecasts.

The poor performance this season appears to be related to the proximity of the majority of the storms to the mountainous coastline of Mexico. The model tended to steer the storms away from the coast. As in previous seasons, the detection rate of storms in this basins was very poor. By T+72 only 20% of storms were still retained by the model.

Figs. 5 and 6 show forecast errors and skill scores for the last few seasons.

3.3 North Atlantic Basin Storms

Table of Mean Error Statistics

	T+0	T+24	T+48	T+72	T+96	T+120
Possibly Verified	155	125	103	83	64	53
Detection Rate (%)	100	99	91	78	67	49
Mean DX	3	-52	-106	-111	-117	-65
Mean DY	4	2	5	-19	-49	-33
Mean AT	-6	-32	-45	-69	-146	-168
Mean CT	11	4	22	17	-8	84
Mean Skill (%)	****	4	31	41	****	****
* 1995 Skill (%)	****	17	42	42	****	****
RT Skill (%) #	****	17	34	42	****	****
Mean DPE	52	151	272	368	488	671
* 1995 DPE	54	144	221	323	445	593
RT DPE #	46	150	269	366	489	671

* DPE and skill for all North Atlantic storms in 1995 season

\# DPE and skill in 1996 calculated using real time observations as opposed to best track.

Comments :

A plot of the observed tracks of all storms in this basin can be found in Fig. 7.

There were six less tropical storms this season than last in the North Atlantic basin, but activity was still above average. Forecast errors were higher than last season although were still lower than those of 1994. Skill scores were lower than last season. There was a slow bias in forecasts. Only half of all forecasts successfully retained storm centres 5 days into the forecast.

Figs. 8 and 9 show forecast errors and skill scores for the last few seasons.

3.4 North Indian Basin Storms

Table of Mean Error Statistics

	T+0	T+24	T+48	T+72	T+96	T+120
Possibly Verified	57	40	26	16	12	11
Detection Rate (%)	100	90	69	31	25	27
Mean DX	-17	-10	6	77	449	606
Mean DY	-5	-42	-105	-56	-89	22
Mean AT	-33	-120	-179	-94	-298	-613
Mean CT	-12	5	57	-2	-261	-251
Mean Skill (%)	****	-28	18	****	****	****
* 1995 Skill (%)	****	9	16	****	****	****
RT Skill (%) #	****	29	42	****	****	****
Mean DPE	76	188	282	119	459	617
* 1995 DPE	56	160	407	566	****	****
RT DPE #	52	181	304	141	406	578

* DPE and skill for all North Indian storms in 1995 season
# DPE and skill in 1996 calculated using real time observations as opposed to best track.

Comments :
A plot of the observed tracks of all storms in this basin can be found in Fig. 10.

There were four more storms in this basin this season than last. T+24 errors were slightly higher than last season, but T+48 errors were slightly lower. There was a slow bias in forecasts. The forecast detection rate was low at T+72 and beyond.

Figs. 11 and 12 show forecast errors and skill scores for the last few seasons.

3.5 Combined Statistics for whole Northern Hemisphere

Table of Mean Error Statistics

	T+0	T+24	T+48	T+72	T+96	T+120
Possibly Verified	614	490	384	296	223	170
Detection Rate (%)	100	98	90	81	77	70
Mean DX	-1	-22	-53	-42	-1	46
Mean DY	4	16	40	53	58	81
Mean AT	-6	-27	-35	-52	-74	-49
Mean CT	2	-7	-6	-5	35	121
Mean Skill (%)	****	-8	30	39	****	****
* 1995 Skill (%)	****	7	33	35	****	****
RT Skill (%) #	****	14	35	41	****	****
Mean DPE	59	164	268	382	503	640
* 1995 DPE	57	162	260	368	519	666
RT DPE #	48	162	268	382	500	637

* DPE and skill for all Northern hemisphere storms in 1995 season

\# DPE and skill in 1996 calculated using real time observations as opposed to best track.

Comments :

Forecast errors for the whole northern hemisphere in 1996 were similar to those for 1995. Skill scores were slightly higher at T+72, but lower at T+24 and T+48. There was a slow bias in forecasts, but little right-of-track bias. 70% of forecasts succesfully retained storms centres 5 days into the forecast.

On average, there was only a small difference between forecast positional errors derived using real time observations and those derived using best track observations. T+24 skill scores tended to be much lower when using best track data than real time data. The reason for this is that when best track data are used, it is not only the verifying observations that are different, but CLIPER forecasts are also recalculated. Since the past observations used to calculate CLIPER forecasts are much better, CLIPER will improve (particularly at T+24 which is more heavily weighted towards persistence). Hence skill scores will reduce. Consequently, comparisons of skill scores derived using real time and best track data must be treated with caution. All figures for 1995 quoted in this paper are using best track data. Prior to 1995 only real time data were used in verification.

Figs. 13 to 16 show forecast errors, skill scores, along and cross track errors over the last few seasons. The level of improvement in forecasts seen in 1995 after the introduction of the new initialisation scheme has been maintained in 1996, although there was some inter-basin variability. For example, North-West Pacific errors were lower, whilst North Atlantic errors were higher in 1996.

Further Tropical Cyclone Information

The Met. Office pages on the World Wide Web contain information on tropical cyclone forecasting at the Met. Office. Monthly bulletins of tropical cyclone activity and forecasts are held together with observed and forecast track information of recent storms, track prediction error statistics, lists of names, images, movies and photographs and details of advances made in tropical cyclone track prediction at the Met. Office.

The Met. Office web site is:- **http://www.met-office.gov.uk**
Tropical Cyclone information can be found under the section "The weather & how we forecast it".

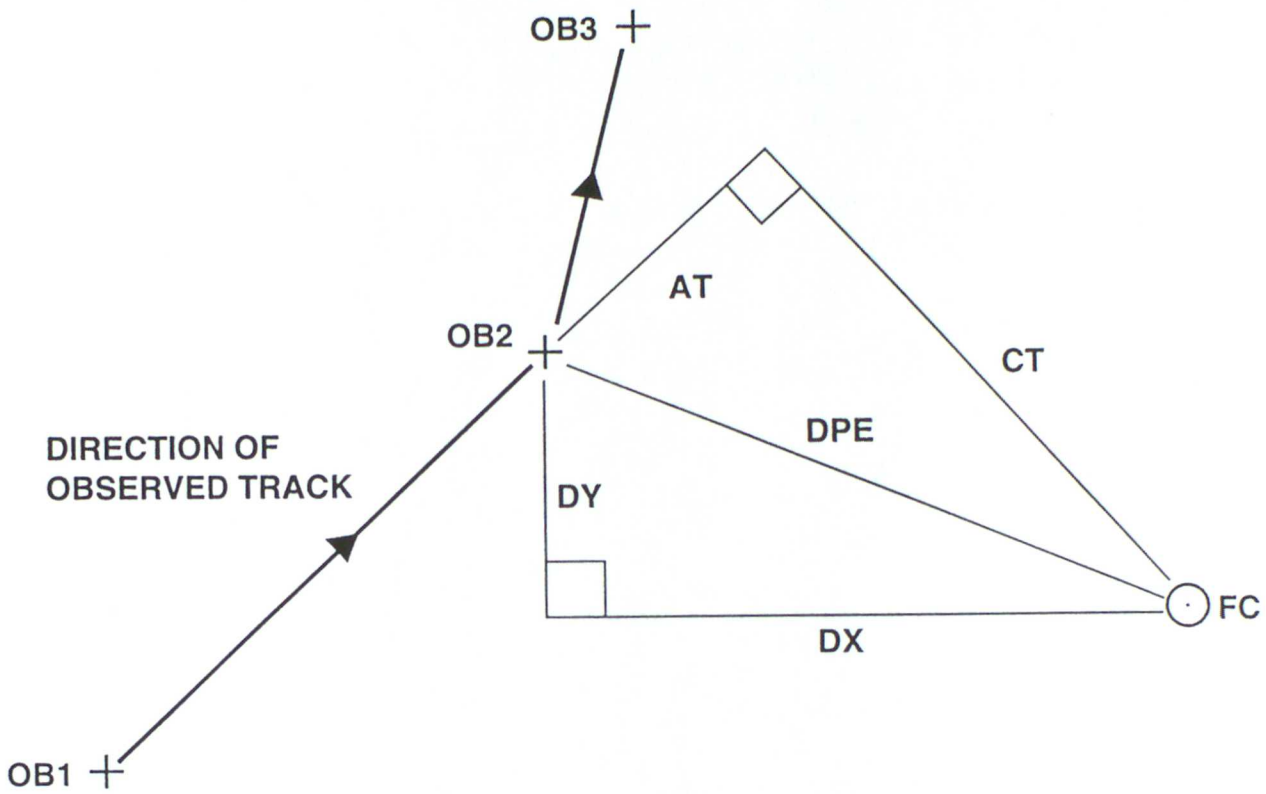
The information above is also available on the Met. Office internal Web:- **http://cf0100/~cfss/tchome.html.**
Contact Julian Heming (**jheming@meto.gov.uk**) or Alan Radford (**amradford@meto.gov.uk**) for further information on tropical cyclone forecasting at the Met. Office.

Acknowledgements

CLIPER models for various basins were supplied by Mr.S.Lord, NMC, Washington, USA and Mr.C.Mauck, FNOC, Monterey, USA. GrADS software used to produce track plotting charts was supplied by Mr.S.Lord and Dr.M.Fiorino.
Best track observations for the northern hemisphere were supplied by Mr.J.Gross, NHC, Miami, Mr.F.Wells, JTWC, Guam and Mr.S.Osano, JMA, Tokyo.

APPENDIX A

Diagrammatic Explanation of Forecast Errors



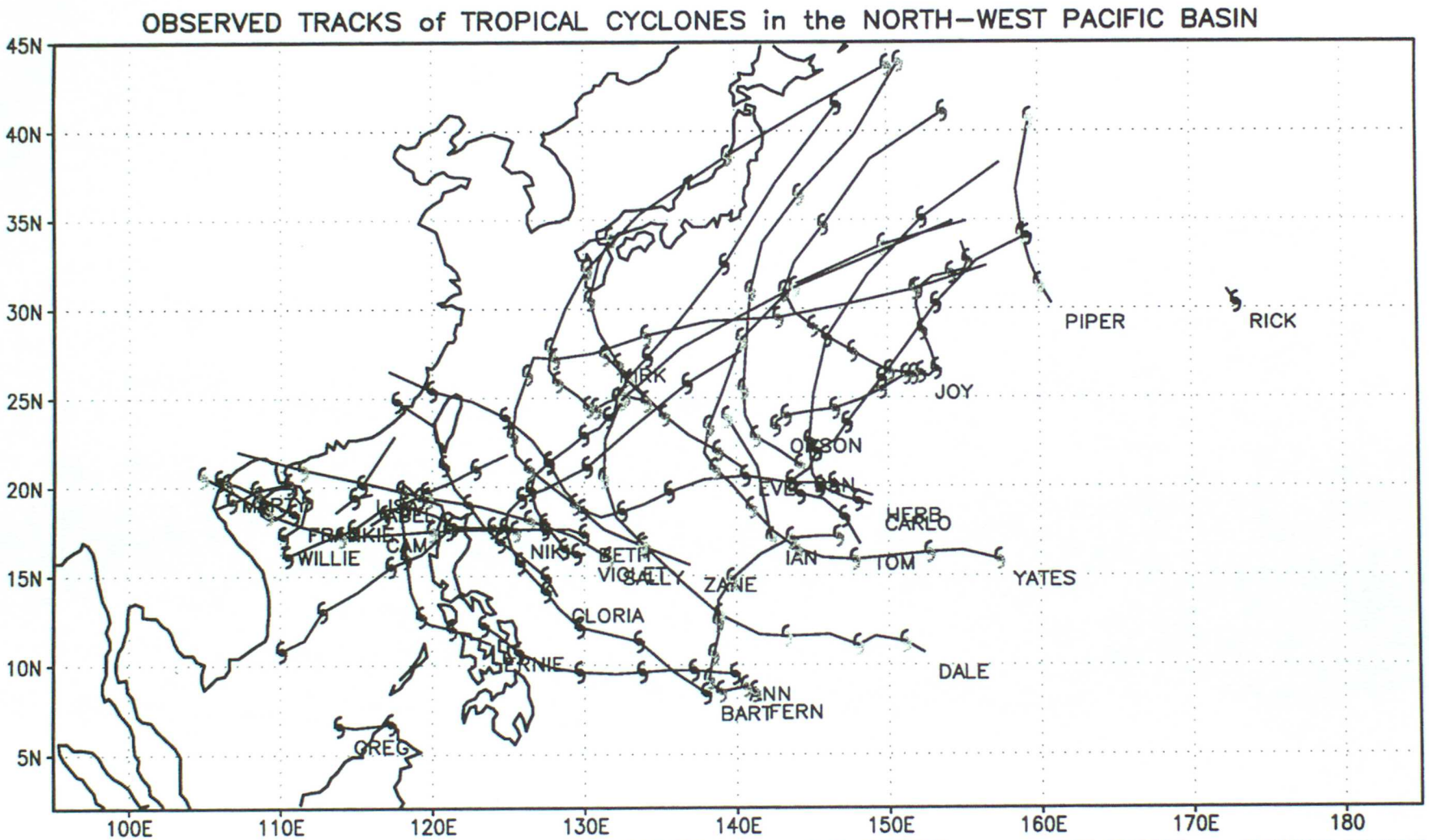
OB1-3 : Observed positions
FC : Forecast position verifying against observation OB2
DPE : Direct positional error
DX : Error in the East-West direction
DY : Error in the North-South direction
AT : Error in the Along Track direction
CT : Error in the Cross Track direction

All errors are measured in kilometres

Sign Conventions

DPE values are always positive.
DX errors are positive if the forecast position lies eastwards of the observed position.
DY errors are positive if the forecast position lies polewards of the observed position.
AT errors are positive if the forecast position lies ahead of the observed position along the tropical cyclone track.
CT errors are positive if the forecast position lies right of the observed track in the northern hemisphere and left of the observed track in the southern hemisphere.

Figure 1



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GLORIA 960723	HERB 960725	IAN 960729	JOY 960730	KIRK 960806	LISA 960806
MARTY 960814	NIKI 960819	ORSON 960823	PIPER 960824	RICK 960830	SALLY 960906
TOM 960913	VIOLET 960913	WILLIE 960918	YATES 960923	ZANE 960925	ABEL 961014
BETH 961015	CARLO 961022	DALE 961106	ERNIE 961107	FERN 961222	GREG 961225

KEY to DATE of FIRST SYMBOL

24 HOURLY BEST TRACK OBSERVED POSITIONS

SYMBOLS REPRESENT 00Z POSITIONS

Figure 2

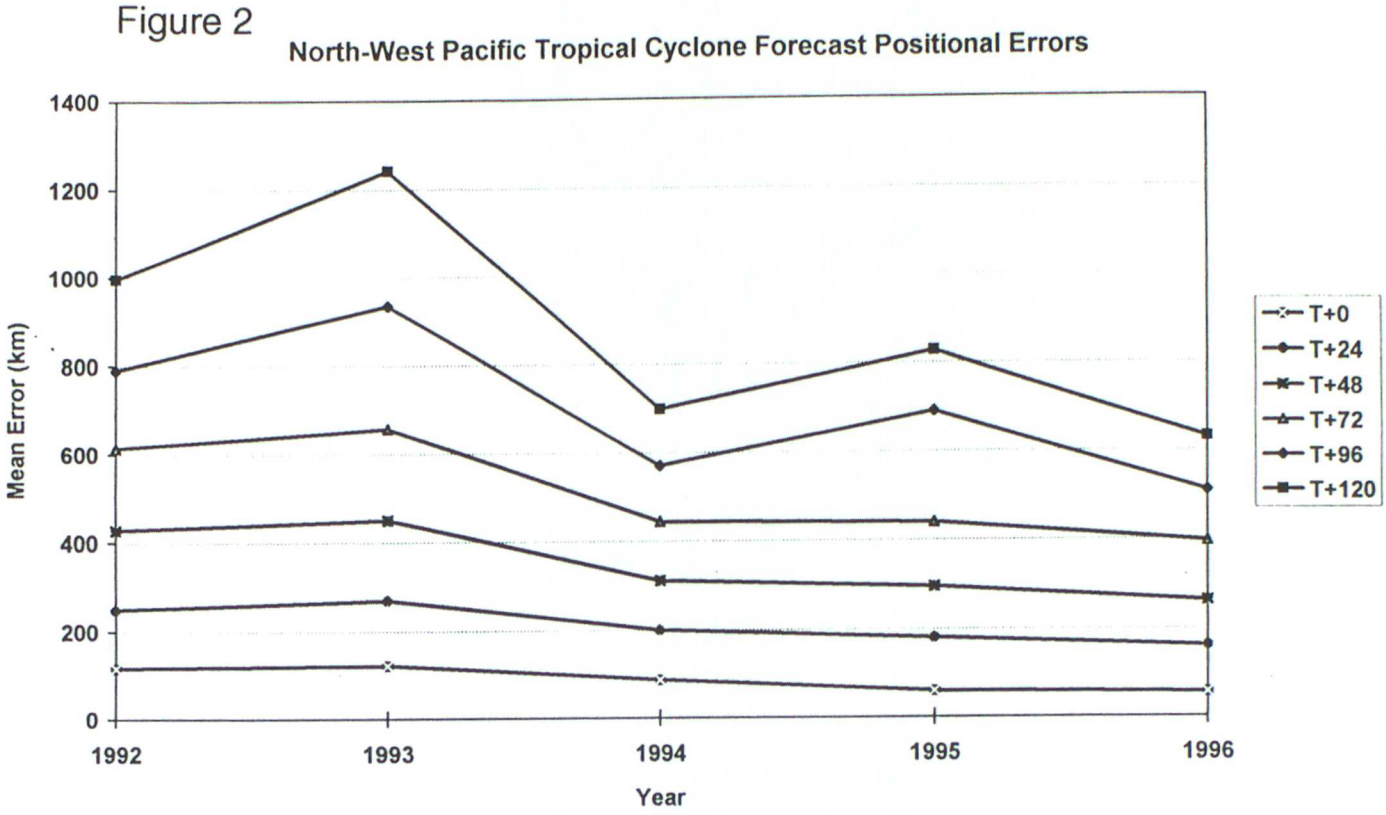


Figure 3

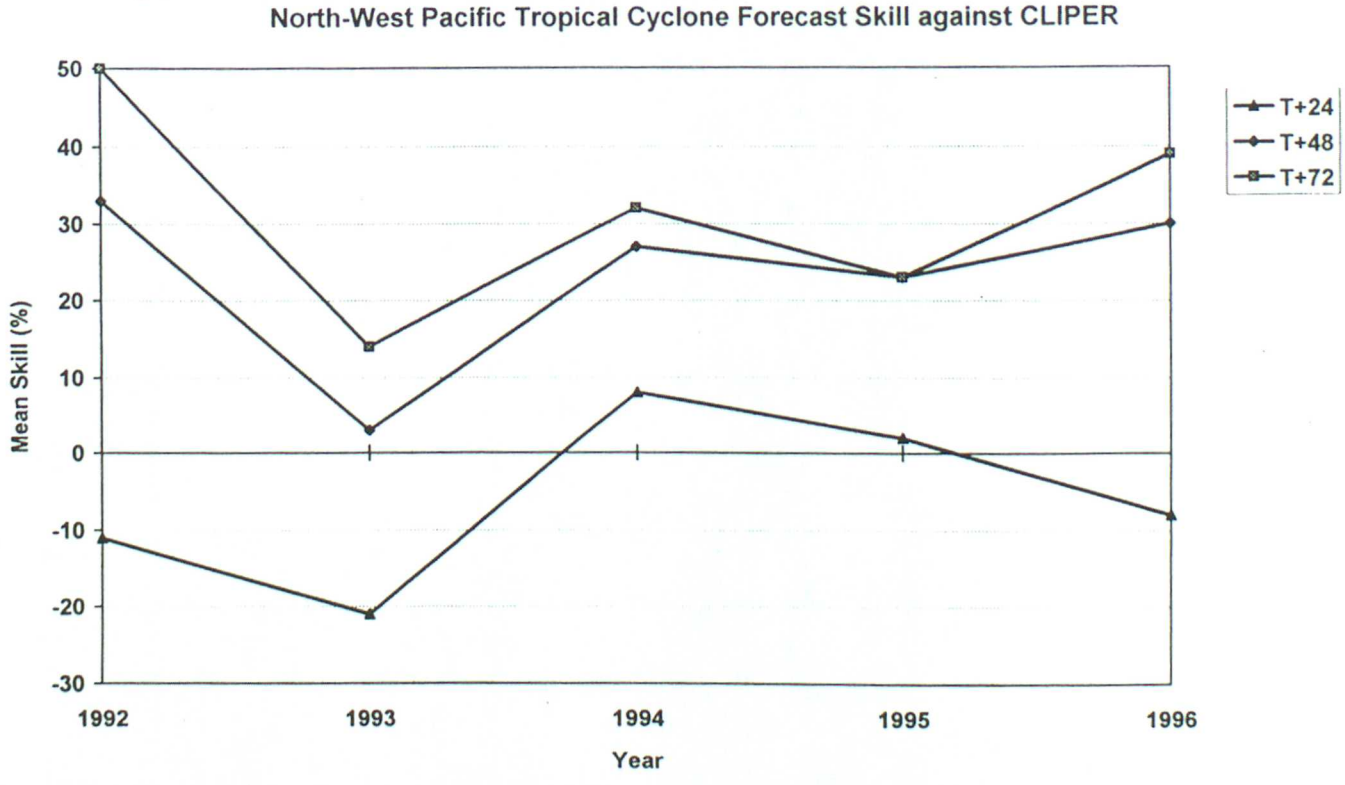


Figure 4

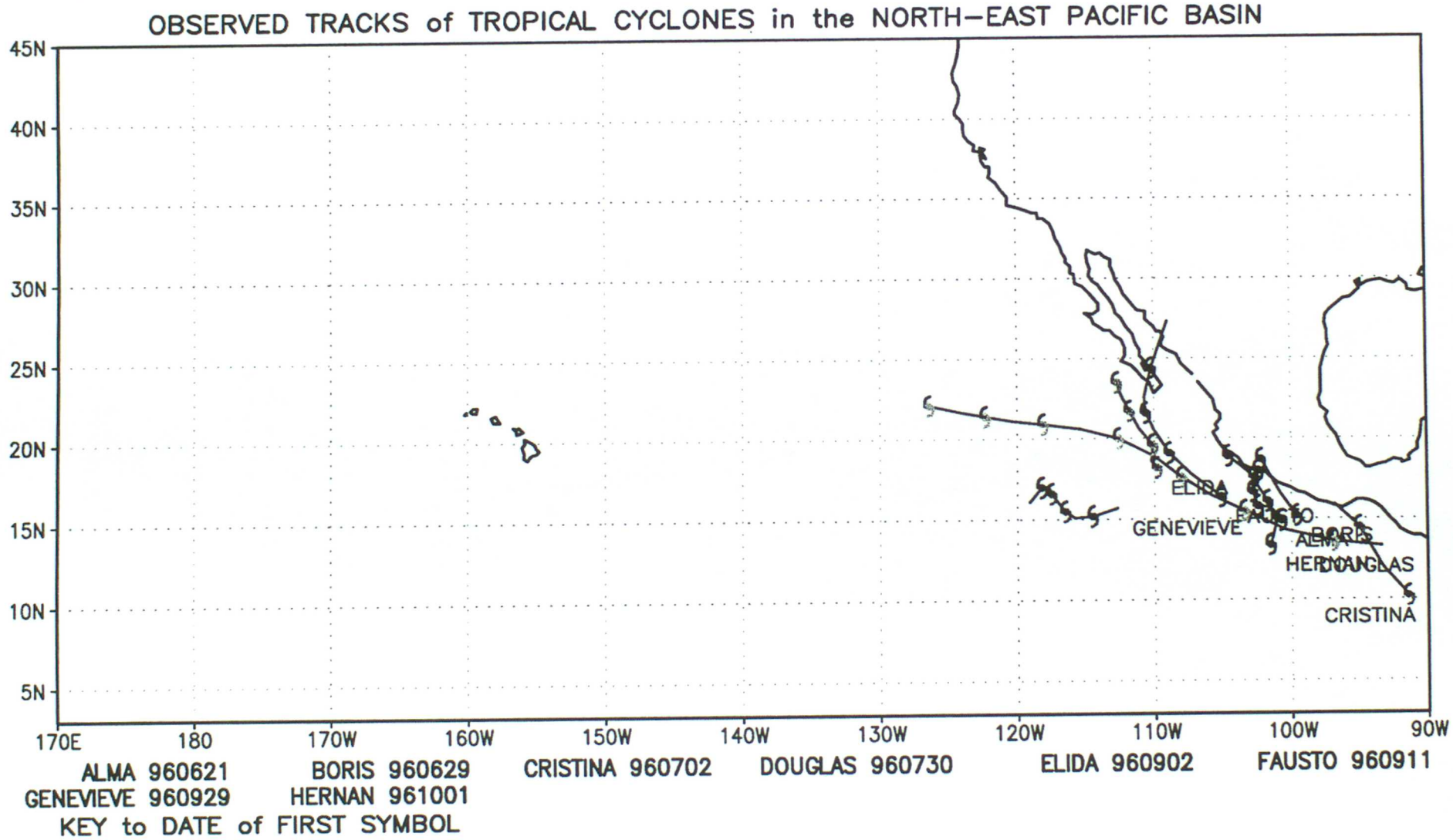

OBSERVED TRACKS of TROPICAL CYCLONES in the NORTH–EAST PACIFIC BASIN
45N
40N
35N
30N
25N
20N
15N
10N
5N
170E
180
170W
160W
150W
140W
130W
120W
110W
100W
90W
ELIDA
GENEVIEVE
CRISTINA
ALMA 960621
BORIS 960629
CRISTINA 960702
DOUGLAS 960730
ELIDA 960902
FAUSTO 960911
GENEVIEVE 960929
HERNAN 961001
KEY to DATE of FIRST SYMBOL
24 HOURLY BEST TRACK OBSERVED POSITIONS
SYMBOLS REPRESENT 00Z POSITIONS

Figure 5

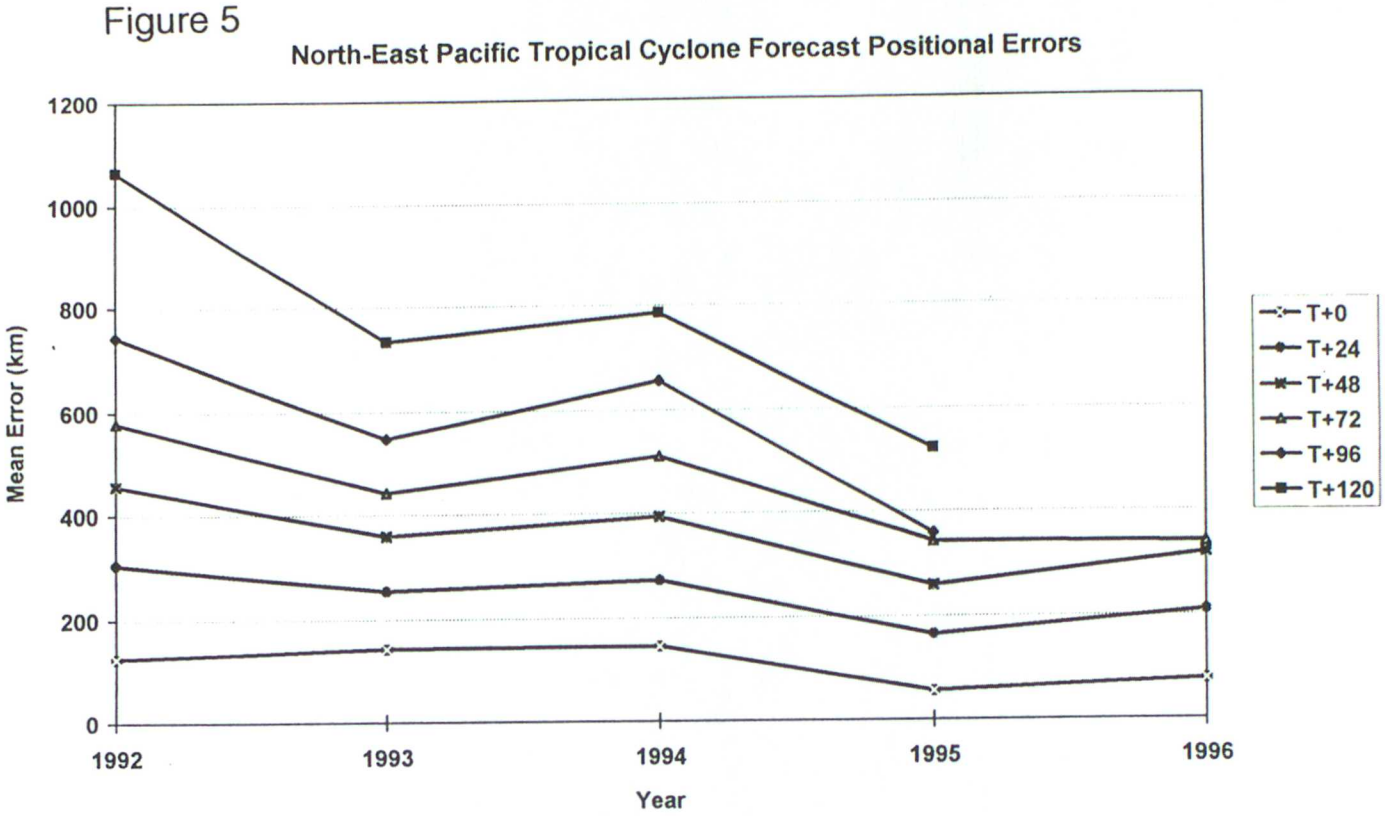


Figure 6

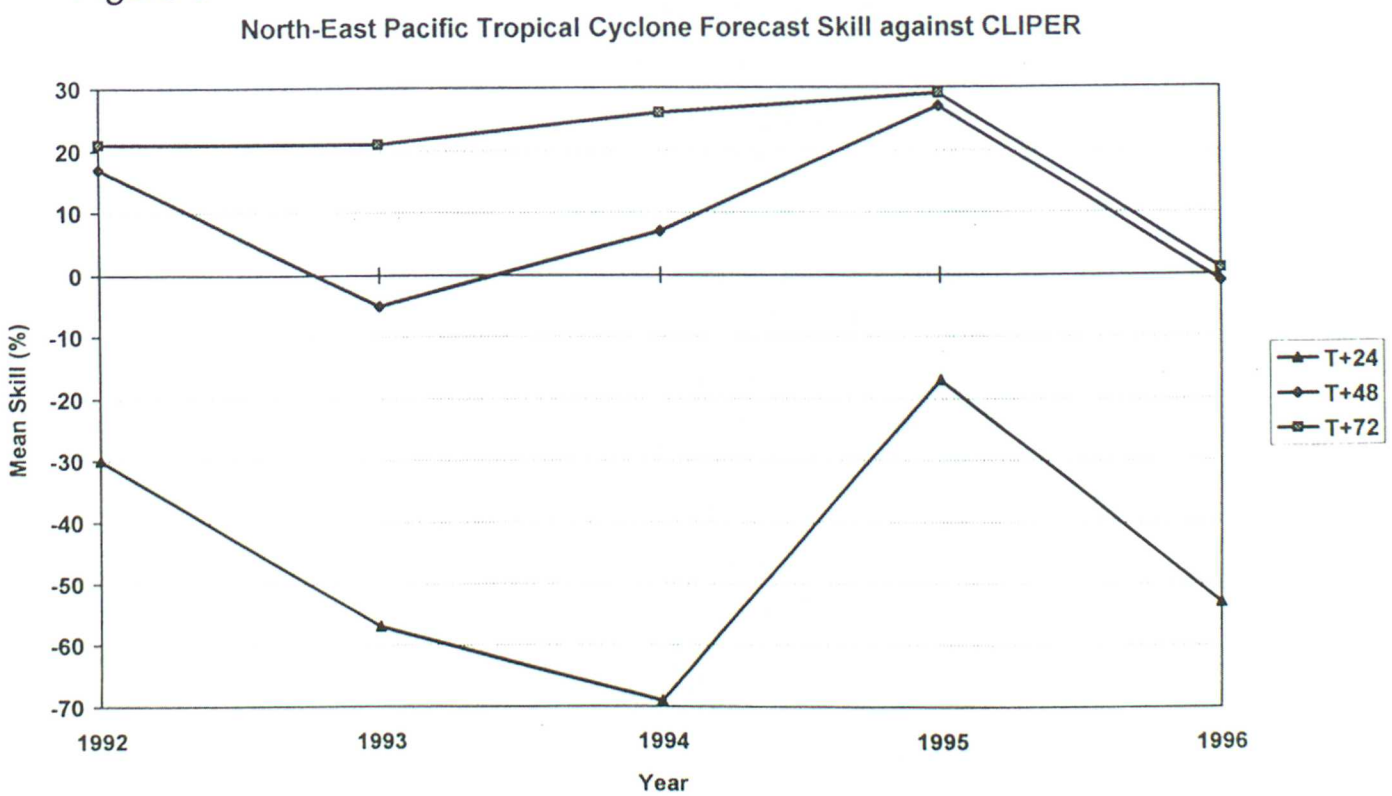
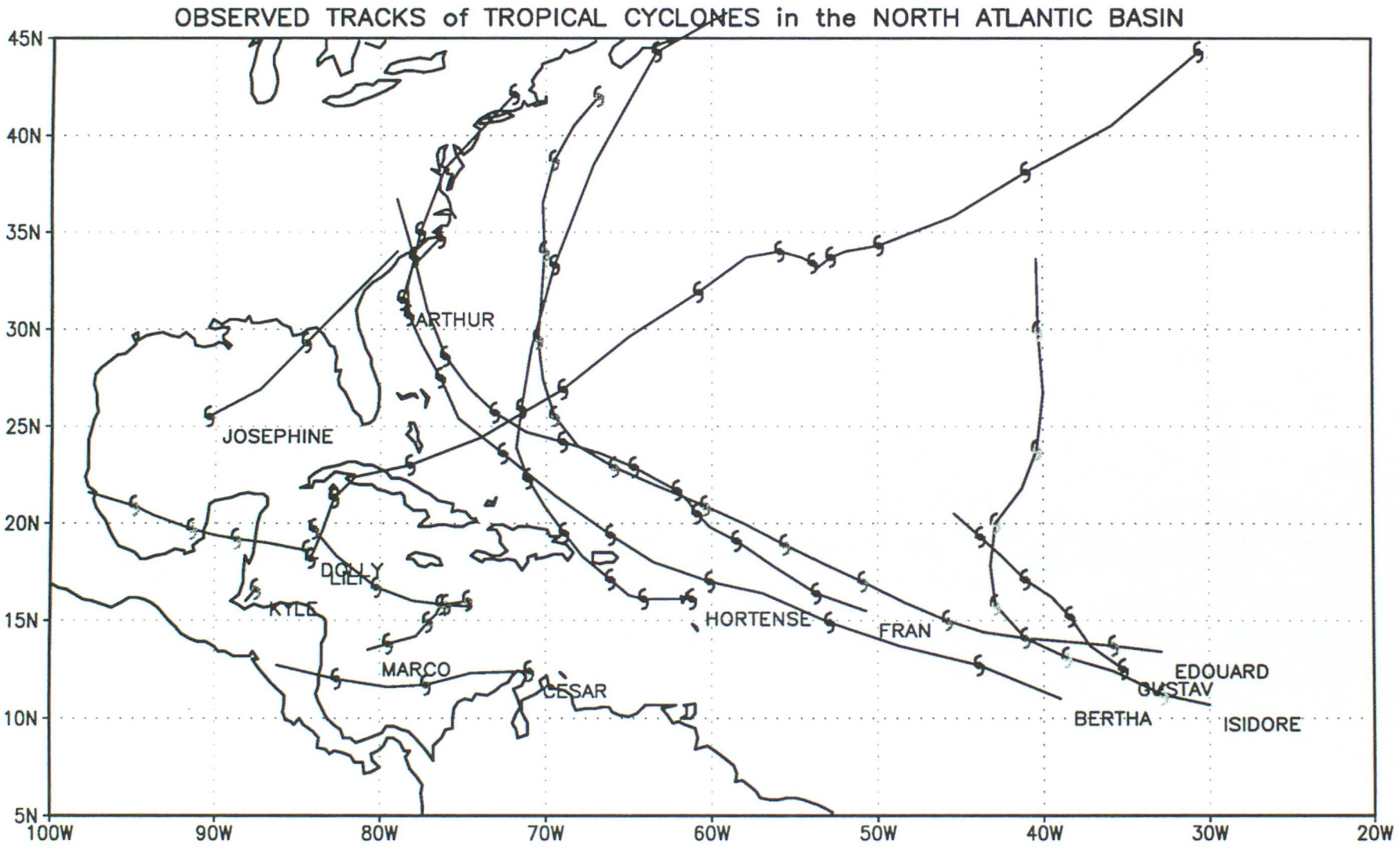


Figure 7


OBSERVED TRACKS of TROPICAL CYCLONES in the NORTH ATLANTIC BASIN
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40N
35N
30N
25N
20N
15N
10N
5N
100W
90W
80W
70W
60W
50W
40W
30W
20W
ARTHUR
JOSEPHINE
DOLLY
LILI
KYLE
MARCO
CESAR
HORTENSE
FRAN
EDOUARD
GUSTAV
BERTHA
ISIDORE
ARTHUR 960619
BERTHA 960706
CESAR 960726
DOLLY 960820
EDOUARD 960823
FRAN 960829
GUSTAV 960829
HORTENSE 960908
ISIDORE 960926
JOSEPHINE 961007
KYLE 961012
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MARCO 961120
KEY to DATE of FIRST SYMBOL
24 HOURLY BEST TRACK OBSERVED POSITIONS
SYMBOLS REPRESENT 00Z POSITIONS

Figure 8

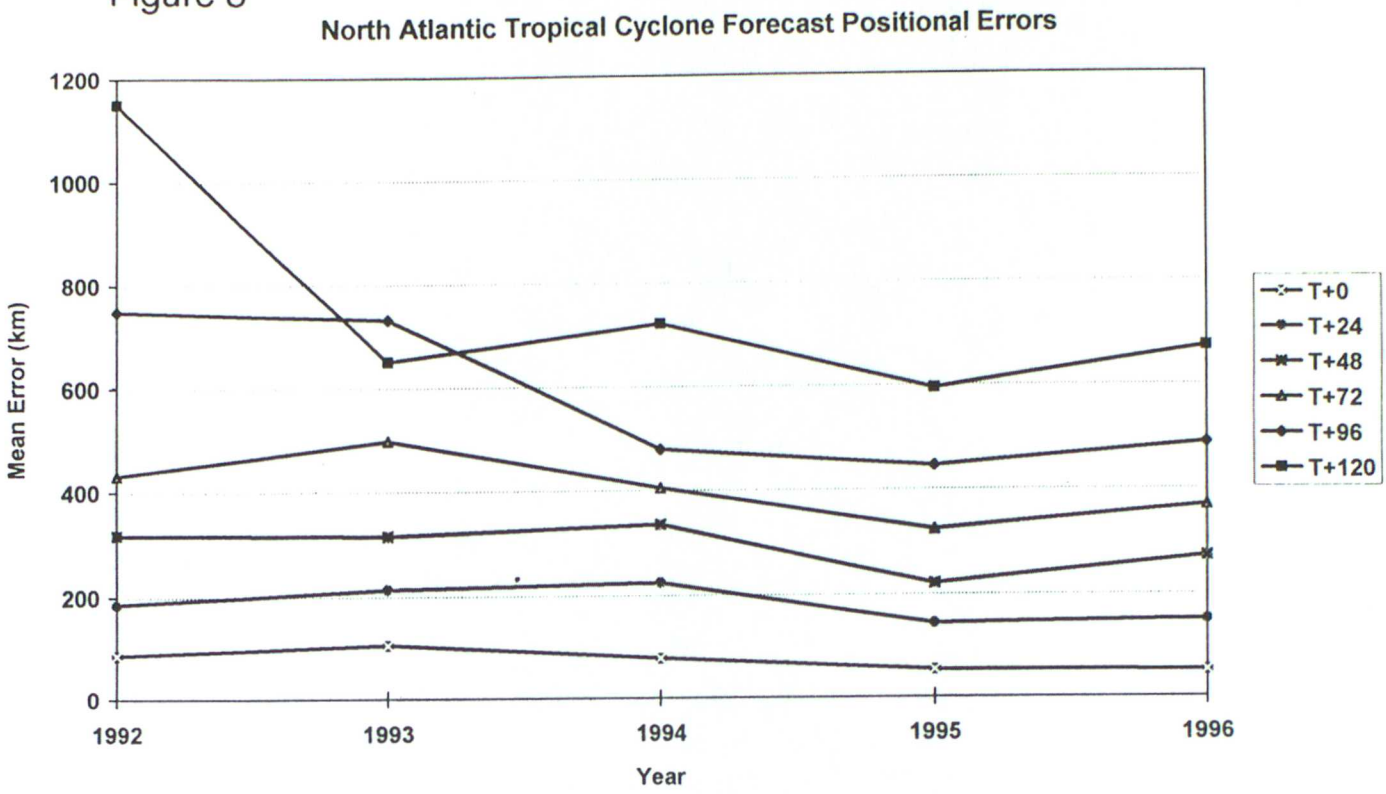


Figure 9

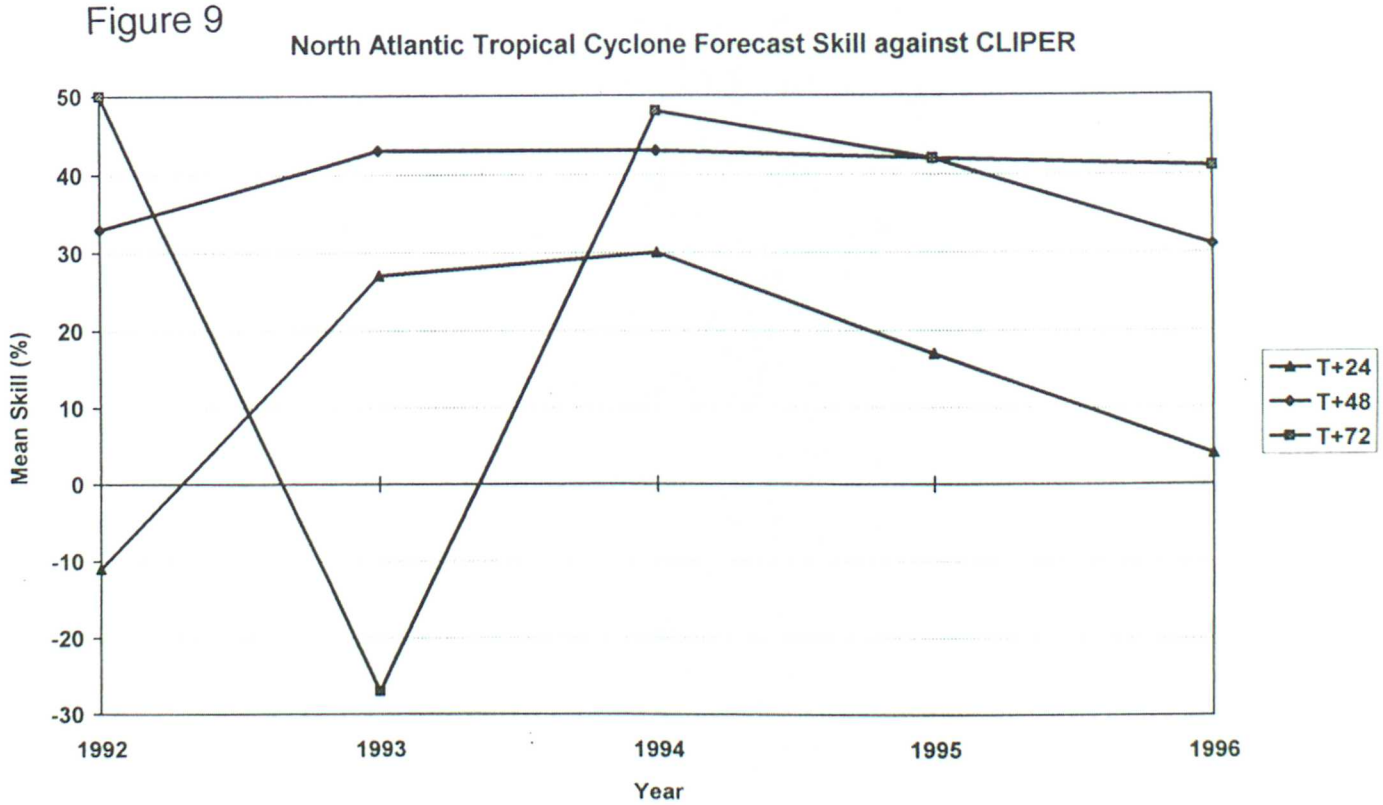
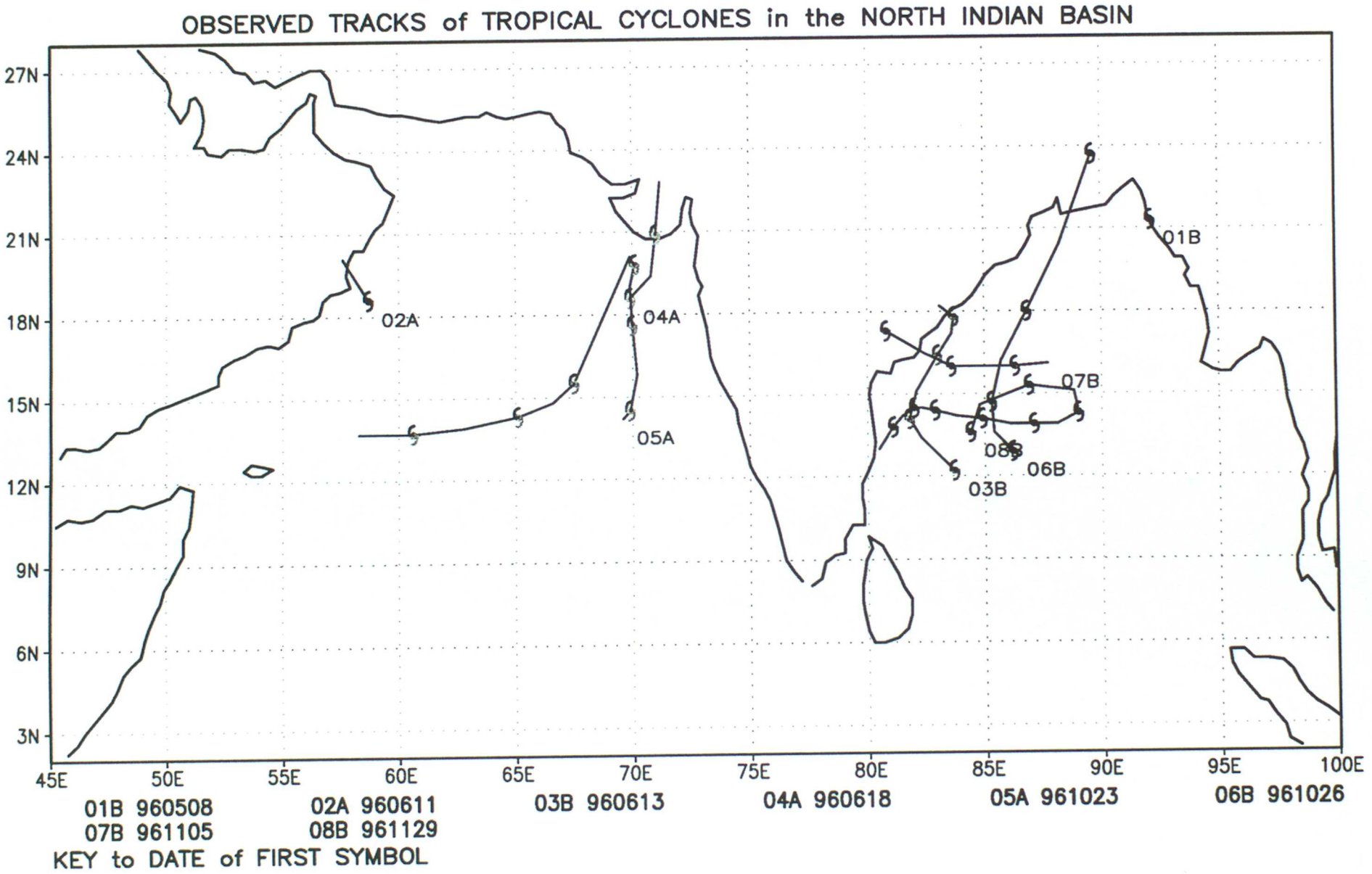


Figure 10


OBSERVED TRACKS of TROPICAL CYCLONES in the NORTH INDIAN BASIN
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21N
18N
15N
12N
9N
6N
3N
45E
50E
55E
60E
65E
70E
75E
80E
85E
90E
95E
100E
01B
02A
03B
04A
05A
06B
07B
08B
01B 960508
02A 960611
03B 960613
04A 960618
05A 961023
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KEY to DATE of FIRST SYMBOL
24 HOURLY BEST TRACK OBSERVED POSITIONS
SYMBOLS REPRESENT 00Z POSITIONS

Figure 11

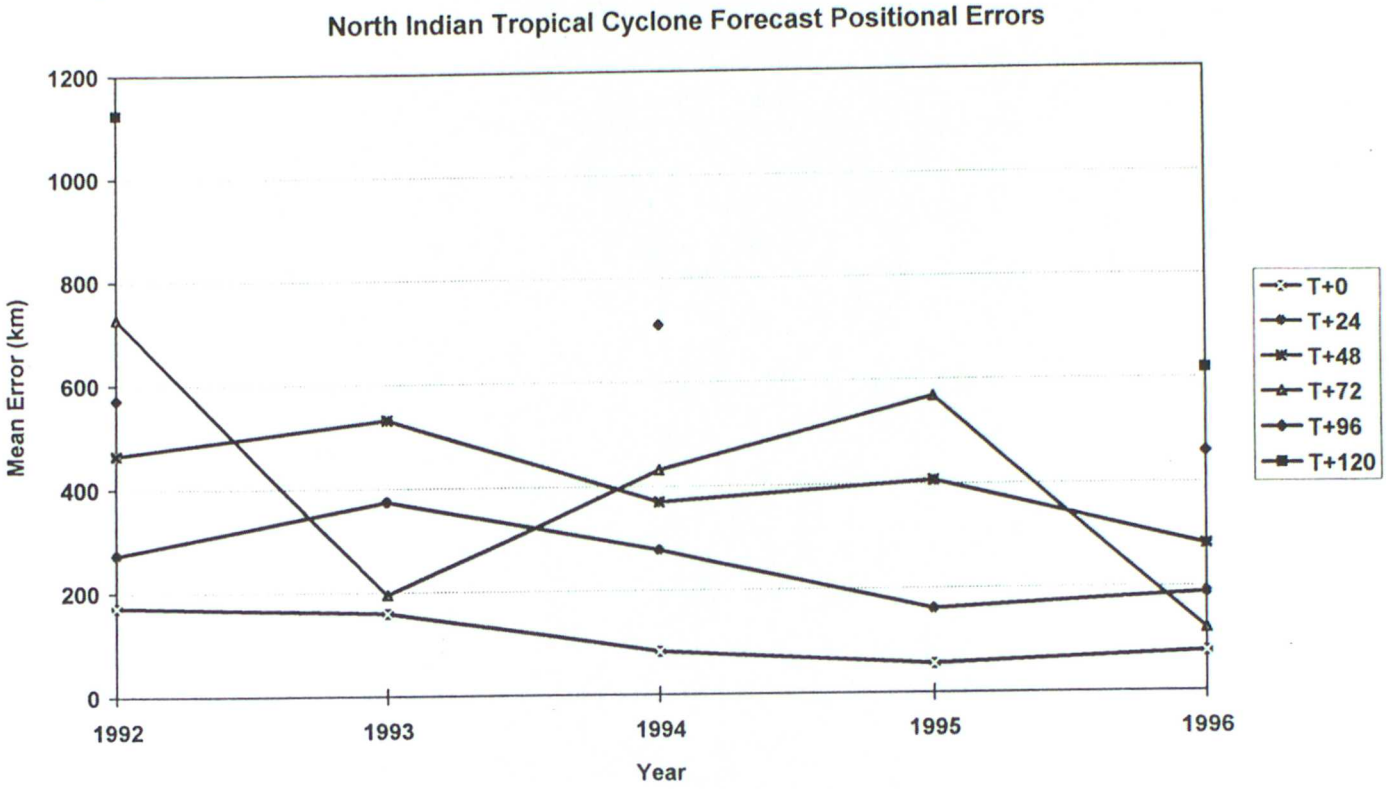

Figure 12

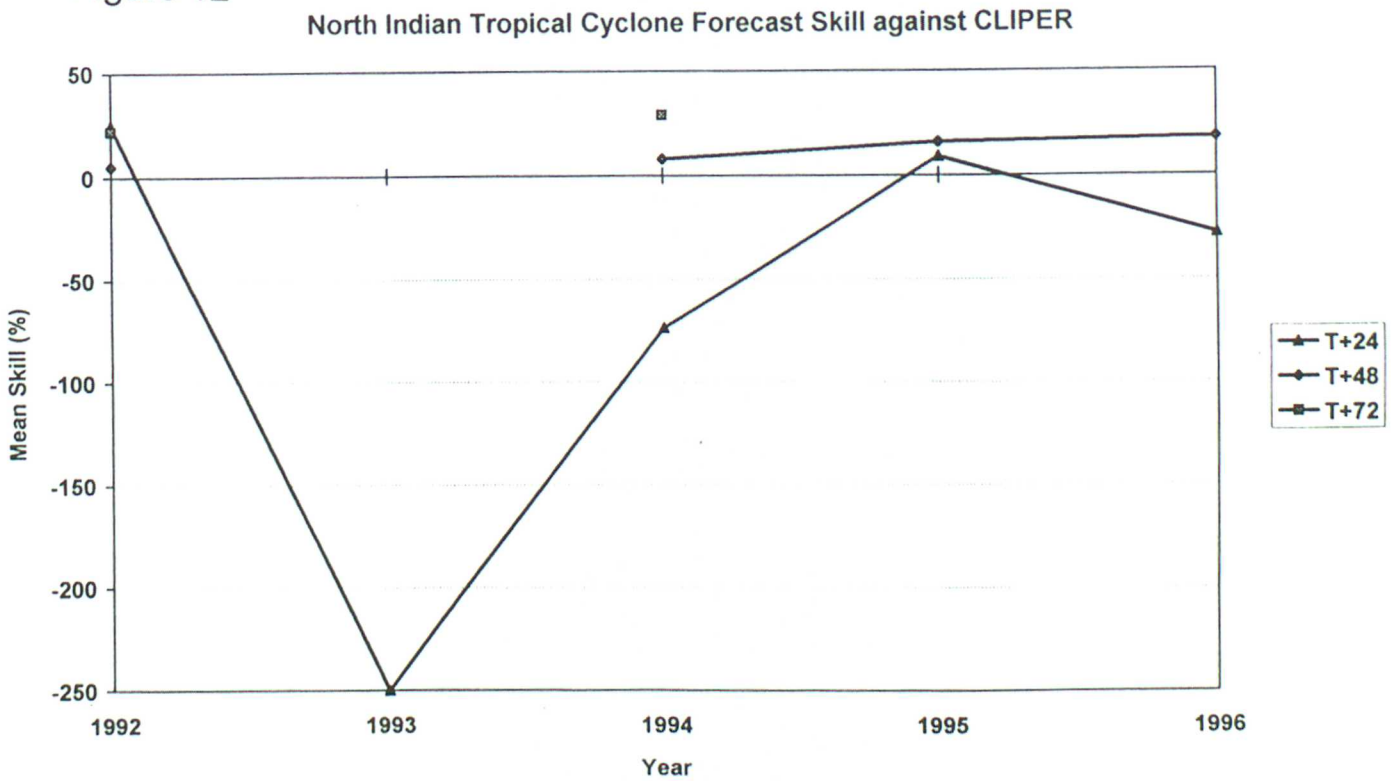

Figure 13

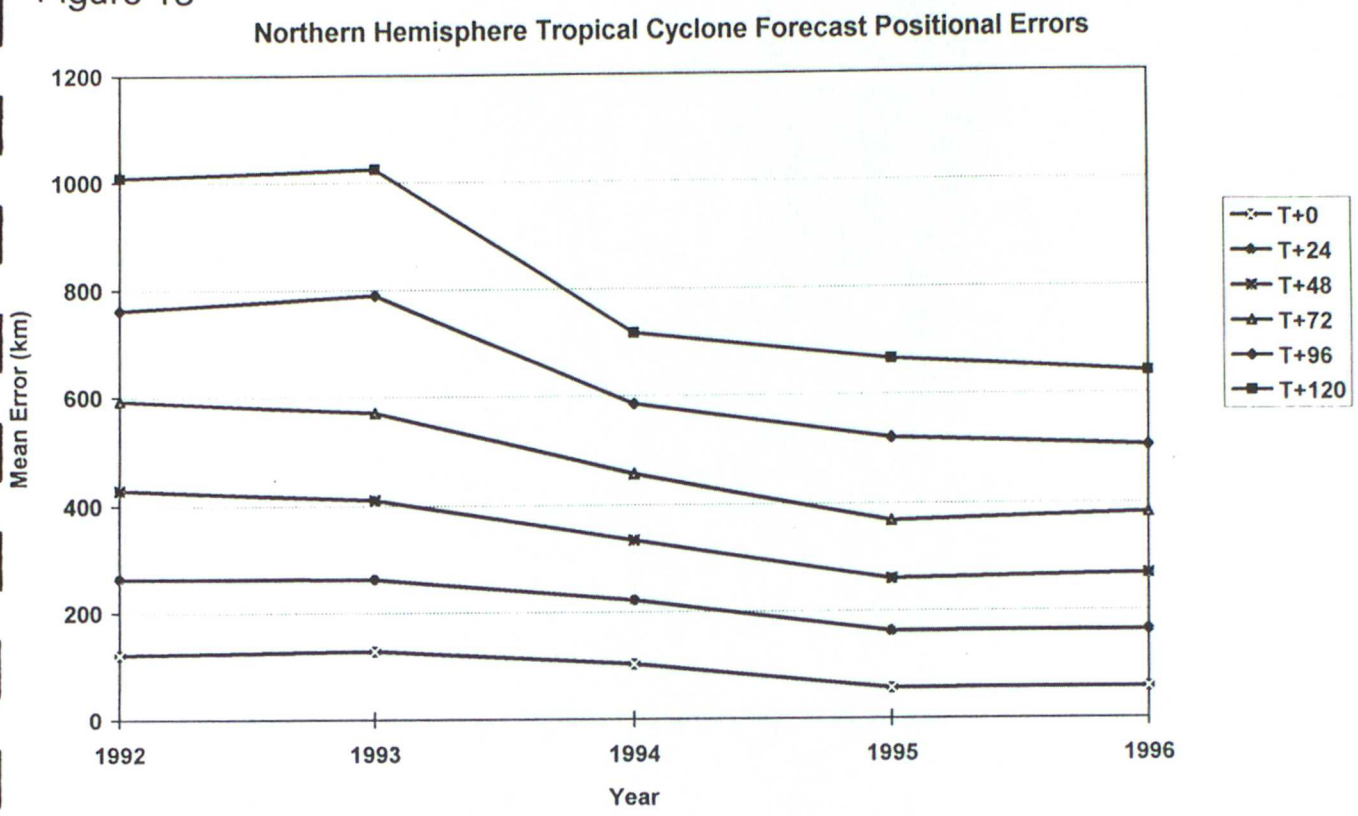

Figure 14

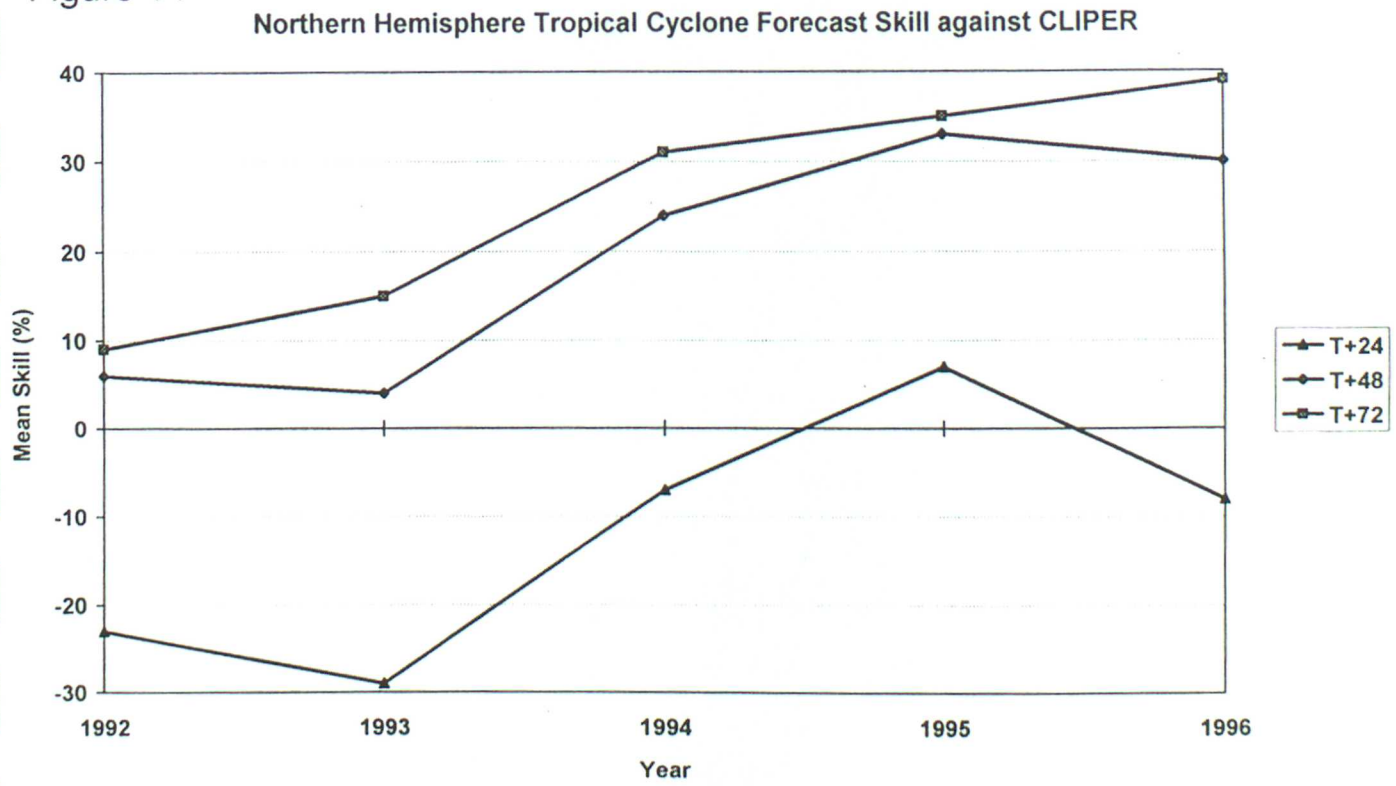

Figure 15

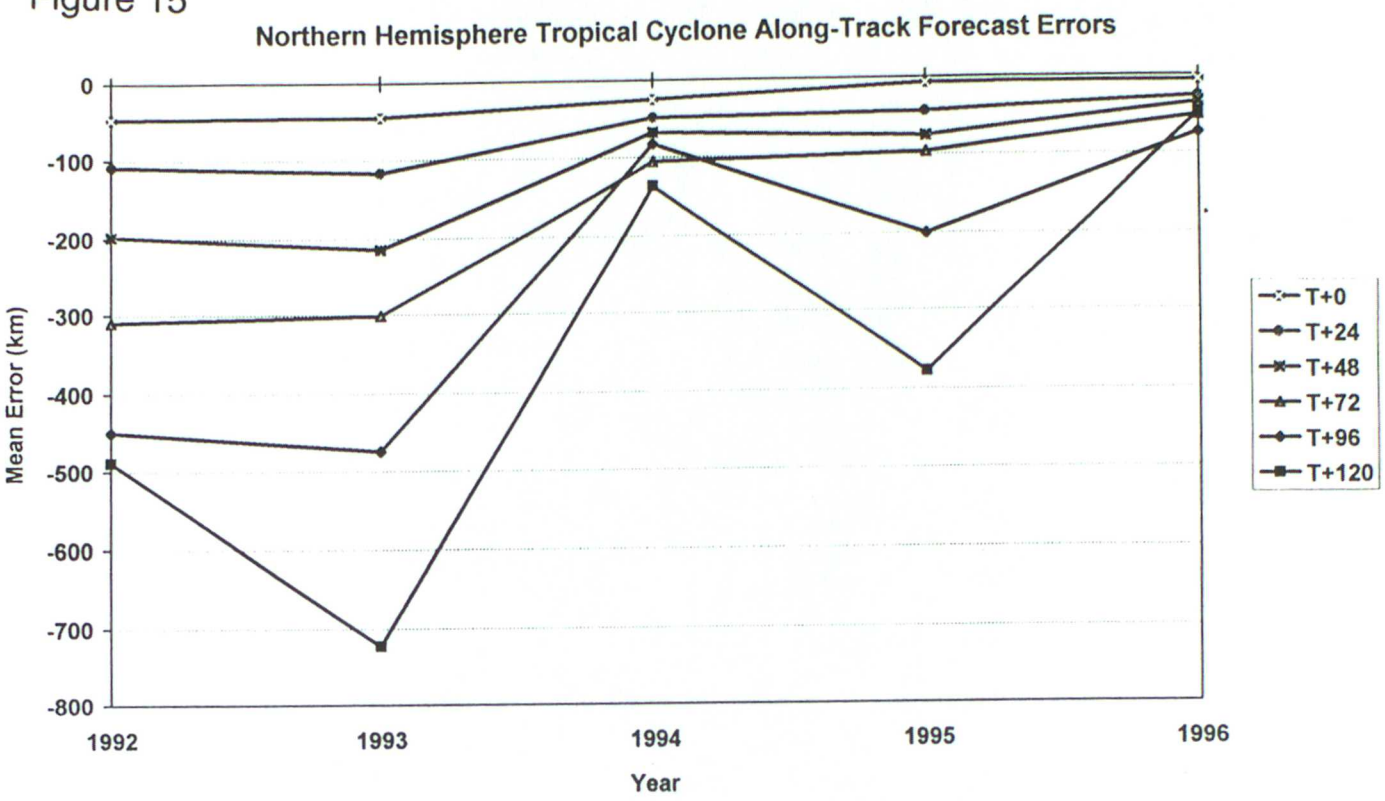

Figure 16